

**Conservation biology of Saimaa ringed seal**  
*(Phoca hispida saimensis)*  
**with reference to other European seal populations.**

Tero Sipilä

Department of Ecology and Systematics  
Division of Population Biology  
University of Helsinki  
Finland

*Academic dissertation*

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Author's address:

Department of Ecology and Systematics

Division of Population Biology

University of Helsinki, FINLAND

P.O. BOX 65 (Viikinkaari 1)

FIN-00014 University of Helsinki

Finland

Mail to: Natural Heritage Services

Metsähallitus

Akselinkatu 8, FIN-57130,

Savonlinna, Finland.

E-mail: [tero.sipila@metsa.fi](mailto:tero.sipila@metsa.fi)

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Tero Sipilä

Department of Ecology and Systematics  
Division of Population Biology  
P.O. Box 65 (Viikinkaari 1)  
FIN-00014, University of Helsinki, Finland.

This thesis is based on the following articles which are referred to in the text by their Roman numerals:

- I** Sipilä, T. (1990). Lair structure and breeding habitat of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) in Finland. - *Finnish Game Res.* 47:11-20.
- II** Sipilä, T. and Kurlin, K. (1992). Infrared videothermography as a method for locating the under-snow lairs of the ringed seal. -In: *Priede, I.G. & Swift, S.M. (eds.) Wildlife Telemetry. Remote monitoring and tracking of animals. Eds. Ellis Horwood 1992. New York - London - Toronto - Sydney - Tokyo - Singapore. pp. 35-40.*
- III** Sipilä, T., Helle, E. and Hyvärinen, H. (1990). Distribution, population size and reproductivity of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) in Finland, 1980-84. - *Finnish Game Res.* 47:3-10.
- IV** Hyvärinen, H., Sipilä, T., Kunasranta, M. and Koskela, J. T. (1998). Mercury Pollution and the Saimaa Ringed Seal (*Phoca hispida saimensis*). - *Mar. Pollut. Bull.* 36:76-81.
- V** Kokko, H., Helle, E., Lindström, J., Ranta, E., Sipilä, T. and Courchamp, F. (1999). Backcasting population sizes of ringed and grey seals in the Baltic and Lake Saimaa during the 20<sup>th</sup> century. - *Ann. Zool. Fennici.* 36:65-73
- VI** Kokko, H., Lindström, J., Ranta, E., Sipilä, T. and Koskela, J. (1998). Estimating the demographic effective population size of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) - *Anim. Cons.* 1:47-54.
- VII** Wilson, S.C., Mo, G. & Sipilä, T. (2001). Legal protection for seals in small populations in European Community and Mediterranean coastal waters. - *Mammalia* 65:335-348.

# CONTRIBUTIONS

The following table shows the major contributions of authors to the original articles.

	I	II	III	IV	V	VI	VII
Original Idea	HH, EH, TS	EH, KK, TS, HH	EH, HH, TS	HH, TS	HK, JL, ER	HK, JL, ER	SW, GM
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HH - Heikki Hyvärinen, EH - Eero Helle, TS - Tero Sipilä, KK - Kalevi Kurlin, HK- Hanna Kokko, JL - Jan Lindström, ER - Esa Ranta, FC - Franck Courchamp, SW - Susan Wilson, GM - Giulia Mo.

Supervised by: Prof. Esa Ranta  
University of Helsinki  
Finland

Reviewed by: Doc. Raimo Virkkala  
Finnish Environment Institute  
Finland

Doc. Nina Peuhkuri  
Finnish Game and Fisheries Research Institute  
Finland

Examined by: Doc. Ilpo K. Hanski  
University of Helsinki  
Finland

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## Introduction

The ringed seal (*Phoca hispida*) is one of the smallest of all living seal species. It is usually associated with waters that freeze and its successful breeding depends on ice and snow. The southern edge of the range where the ringed seal can breed is in water with solid annual ice cover and where snowdrifts pile up. Stable winter-time ice with ample snow cover is considered the most productive habitat for this species (Ognev 1934, Mohr 1952, Scheffer 1958, Helle 1983, Bonner 1989, Reeves *et al.* 1992, Jefferson *et al.* 1993, Reeves 1998).

The subspecies status is generally recognised in the exceptionally southern ringed seal populations as in Lake Saimaa (*Phoca hispida saimensis*), in the Baltic Sea (*P. h. botnica*) and in Lake Ladoga (*P. h. ladogensis*) which have had a well-known isolation history since the last glacial period. Likewise, the ringed seal subspecies *P. h. ochotensis* in the Sea of Okhotsk also has a quite separated southern distribution area (Nordquist 1899, Scheffer 1958, Müller-Wille 1969, Frost and Lowry 1981, Lappalainen 1984, Hyvärinen and Nieminen 1990, Reijnders *et al.* 1993, Rice 1998). Some northern European lakes other than Saimaa and Ladoga were inhabited by the seals after the last glacial period, but those populations have vanished, most likely due to human activities (Ukkonen 1993).

Lake Saimaa, actually a lake complex, is split into smaller lakes, such as lakes Kolovesi, Joutenvesi, Haukivesi and Pihlajavesi, which are separated from each other by narrow straits (I, III, VI). The total area of Lake Saimaa is 4 460 km<sup>2</sup> and it is a highly fragmented lake complex totalling some 13 710 islands and islets. The shoreline length of the lake complex is approx. 15 000 km, while the maximum length of the lake is 194 km and maximum width 138 km; the deepest point is 82 m and the mean depth is 17 m. The mean difference of water surface level from the northernmost point to the southernmost point of Lake Saimaa is only about 23 centimetres (Becker and Sipilä 1984a, Lappalainen 1984, Kuusisto 1999).

The Saimaa ringed seal was one of the first subspecies which the IUCN included on the Red List of Threatened Animals, the so-called Red Data Book, and at present its conservation status is regarded as endangered (IUCN 1996, Helle *et al.* 1998, Rassi *et al.* 2001). In total there are 35 species of seals world-wide, but only four of them occur permanently in the waters of the European Union: the Mediterranean monk seal (*Monachus monachus*) which is the only critically endangered seal species in the world; the harbour seal (*Phoca vitulina*), the grey seal (*Halichoerus grypus*) and two subspecies of ringed seal, in the Lake Saimaa and in the Baltic Sea. The Habitat Directive from the European Union classified the Saimaa ringed seal in a category of species that needs strict protection (Council Directive 92/43/EEC, Annex IV) and the subspecies is even listed in the Federal Register of the Department of Commerce, U.S.A., as an endangered and threatened species (Anonymous 1992, 1993, Reijnders *et al.* 1993, IUCN 1996, Brasseur *et al.* 1997, Rice 1998).

Conservation biology aims to solve practical nature protection problems by using scientific methods, e.g., how to protect biodiversity or to retain endangered populations (Soulé 1986). All the threatened species are facing a more or less noticeable probability of extinction in a short time-frame (Belovsky 1987). Nowadays the risk of extinction is almost invariably increase by various human activities. This is also the case with the Saimaa ringed seal, and hence conservation actions with this subspecies focus on the question: What should be done to avoid the extinction of the population? (Ranta *et al.* 1996).

## Objective of the thesis

Presence of winter-time snowdrifts is the essential element for successful lairing, and hence snowdrifts are the key elements in breeding habitats of ringed seals (Chapkskii 1940, McLaren 1958, Smith and Stirling 1975, Lukin and Poletov 1978, Lydersen and Gjertz 1986, Kelly 1988). Ilkka Koivisto's research group made an attempt to describe the breeding habitat and population status of the Saimaa ringed seal in the late 1960's and early 1970's. At that time the relatively comprehensive work was left unfinished and the results were only partly published (e.g. Koivisto 1968, 1972). The first aim of the present protection studies that commenced in the early 1980's, was to describe the lairing and breeding habitat of the Saimaa ringed seal and to apply various lair study methods to the Lake Saimaa population (I). The lair of the ringed seal with a hole into the water and the seal inside the lair is also a source of heat in the snowdrifts, which renders the infrared video camera method feasible (II).

Prior to the studies presented in this thesis only quite rough estimates of the state of the Saimaa ringed seal population were available. Scheffer (1958) evidently "guestimated" the extant population size to be something between 2 000 and 5 000 individuals in Lake Saimaa. Even as recently as in 1981 the prestigious "Handbook of Marine Mammals" (Frost and Lowry 1981) reported these figures. To keep a small population vital and even to enhance its size, it is necessary to have information on the most important population parameters, such as birth rate, mortality and age structure (III). Such data render management and conservation acts possible. Hence, new up-to-date information about the present status of the Saimaa ringed seal population is also presented in this summary based mainly on the methods of the original papers of this thesis. Giving the up-to-date information in this thesis is considered necessary as a considerable time has elapsed since publications I and III.

The small volume and area of most freshwater lakes makes them relatively vulnerable to human-caused pollution and other disturbances. Organochlorine pollution is known to affect the breeding potential and the overall state of health of seals. Out of the anthropogenic heavy metals, mercury is one of the most noxious, seriously affecting a wide range of organs in ringed seals, and may even reduce the resistance of individuals to various diseases (Reijnders *et al.* 1993, Reeves 1998). In the Bothnian Bay, high concentrations of organochlorines correlated with the observed decrease in birth rate of ringed seals (Helle 1980b, 1985, Helle *et al.* 1976). In Lake Saimaa the concentrations of PCBs and DDT, the most well known organochlorides, occur in relatively low concentrations, and burdens of organochlorides probably do not affect breeding of the Saimaa ringed seal at present (Helle 1985, Helle *et al.* 1983, 1985, Kostamo *et al.* 2000). However, very high concentrations of mercury were found in tissue samples of the Saimaa ringed seal collected in the 1960s (Helminen *et al.* 1968, Henriksson *et al.* 1969). It is generally accepted that the toxicity of mercury for ringed seals is reduced by immobilisation of mercury to the liver by selenium (Smith and Armstrong 1978, Kari and Kauranen 1978). Thus, it was considered relevant (IV) to assess the possible impact of mercury on the well-being of Saimaa ringed seals.

The general historical attitude that seals are harmful pests for fishermen (Anonymous 1855, Mela 1882, Ylimaunu 2000) is probably the main reason for ringed seal hunting in Lake Saimaa, although carcasses were also used in earlier times e.g. to produce oil (Sipilä 1981, Kilkki and Marttinen 1984). For example on Lake Puruvesi and some locations of Lake Orivesi ringed seals were harvested to extinction as late as the 1950's (Sipilä 1981, 1994, Hyvärinen *et al.*



1984, 1999a, Kilkki and Marttinen 1984). As a victory for the conservation movement the Saimaa ringed seal was protected in March 4, 1955 by a statutory decree based on the Hunting Act (Decree N.0109/1955). At that time there were no good estimates available about the size of the seal population, but several hunting societies proposed a total ban on harvesting to the State of Finland. Ironically enough, the concern about protection was because the extant population size was too small to be a target of profitable hunting (Becker and Sipilä 1984b). When using proper population models, past bounty statistics can be used as a basis for estimation of historical population sizes of the target species, hence bounty data are used here to backcast seal population sizes in the Baltic Sea, and also in Lake Saimaa (V).

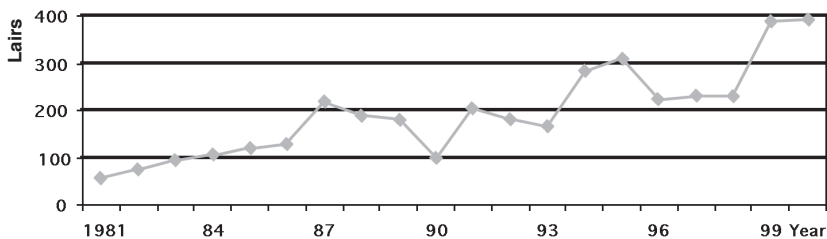
The size of the Saimaa ringed seal population, now being over 200 seals, is well beyond the limit of 100 individuals that is traditionally regarded as being safe from demographic stochasticity (Lande 1988). However demographic stochasticity may have profound effects on a population having a complex structure; differences in age, social status or spatial distribution may account for increased vulnerability. Kokko and Ebenhard (1996) proposed a method of correcting population size for such effects, resulting in an estimate of the demographic effective population size,  $N_D$  of a population. The method was also applied to the Saimaa ringed seal (VI).

The protection and management of a target population is always an active process. At present, the 1992 Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Flora and Fauna, the so called “Habitat Directive” is a principal collection of acts giving rough guidelines for the protection of endangered populations in Europe. It also contains the aim of protection as favourable conservation status and directs the creation of a network of Special Areas of Conservation, better known as the “Natura 2000” -network. In this thesis the effects of the Habitat Directive on the national legislation and protection of the Saimaa ringed seal are also evaluated (VII).

## Extended summary

### *Lair studies*

Saimaa ringed seal lairs were visually located at the end of the lairing period, in late April-early May, when the roof of the lair has usually already collapsed and the lair is disintegrating due to spells of mild weather in spring. In Lake Saimaa, the only possibility of digging a lair, typical of the ringed seal, is to build it into snowdrifts along the shorelines. A lair in Lake Saimaa is located approx. 50 cm from the waterline. Year after year lairs are often located in approximately the same spot on any part of the shoreline known to harbour lairs. During the period 1981 - 2000 a total of 3 874 lairs were detected (Fig. 1) (I, III, updated information).



**Fig. 1.** Numbers of annually observed lairs in Lake Saimaa, 1981-2000.

The structure of the Saimaa ringed seal lairs (haul-out lair and birth lair complex) matches that of ringed seals breeding in the Arctic, in Lake Ladoga and in the Baltic Sea. It is also typical of ringed seals that birth lair complexes are quite easy to distinguish from haul-out lairs of non-breeding individuals at the end of the lactation period. The Baikal seal (*Phoca sibirica*) also has lair structures similar to ringed seals (Pälsi 1924, Jääskeläinen 1925, Ognev 1935, McLaren 1958, Smith and Stirling 1975, Lukin and Poletov 1978, Helle *et al.* 1984, Lydersen and Gjertz 1984, Kelly 1988, Belikov and Boltunov 1998, Kunnasranta *et al.* 2001, Martínková *et al.* 2001). A lair with a still-born dead pup in Lake Saimaa is about the same size as a haul-out lair of a male and female seal without a pup (I).

Lair counting and classifying them as birth lairs and haul-out lairs is a rather accurate method of estimating pup production for a given area (Smith and Stirling 1978, Lydersen *et al.* 1990, Lydersen and Ryg 1991). Site fidelity of the Saimaa ringed seal in combination with relatively small snowdrifts, and shallow water under the lairs also gives quite good possibilities to find natal hair (lanugo) and remains of delivery, either placentas or still-born pups (Kunnasranta 2001, Koskela *et al.* 2002, I, III).

Subnivean lairs with an access hole to the water and/or a seal inside are a distinct heat source in a snowdrift. Lair sites were video-recorded from a helicopter by infrared (IR) video camera in March 1986, 1988 and 1990. Videotapes were analysed by computer using the Thermogram program. The identified positions of heat sources using an IR-videosystem of the possible lairing sites were subsequently located in the field in April (I, II). However, near shorelines there are also other heat sources, such as subnivean water and boulders. The heat radiation from those sources overlaps with heat radiation profiles from the lairs. A modest computerised manipulation (relying on the oval shape of a lair) of the video image enhanced the identification of lairs (II).

### *Backcasting population size*

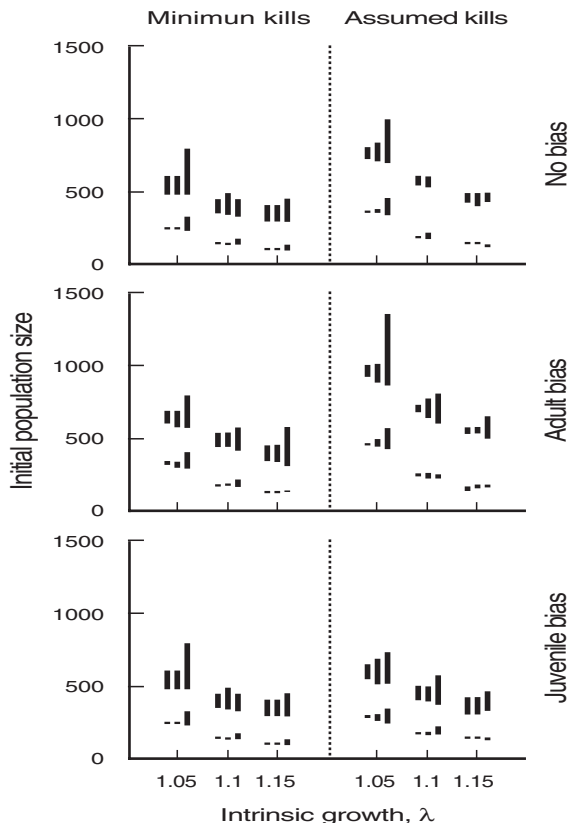
Annual bounty statistics are the only systemically amassed data of the Saimaa ringed seal population until the onset of the population monitoring presented in this thesis. Despite the large effort in collecting field data during the study years, the extant information is still too scanty to build up an accurate life table for the Saimaa ringed seal. We used published life history data in the modelling (Smith 1973a). The sex ratio of offspring born was assumed to be typical of the ringed seal, 1:1 (V, see also III). With a Leslie matrix technique one can project population structure one time step ahead, based on current population structure. Thus, for the Saimaa ringed seal, subject to hunting (i.e.,  $h_t$  individuals removed annually from the breeding population) we have

$$x_{t+1} = Ax_t - h_t$$

where the transition matrix  $A$  contains the survival and fecundity values of the population and age-group-specific individual numbers at time  $t$  are in the column vector  $X_t$ .

As there are many uncertainties concerning long-term data on the Saimaa ringed seal, we constructed different scenarios in our backcasting simulations. In these scenarios bounty statistics were assumed to be (i) accurate including all the killed seals or (ii) imperfect so that the records of bags reflect only 90% of true kills. For years with bounty data missing, we assumed a minimum of 20 seals killed. The population structure was reduced to three age groups, with

(iii) each class being equally vulnerable to hunting, with hunting being confined to (iv) adults or to (v) young seals. We also varied population growth rate ( $V$ ).



**Fig. 2.** Backcasted population size in 1893 for the Saimaa ringed seal. The bars indicate approximate 90% confidence intervals for population backcasts under different scenarios. For the details, see (V).

The lowest backcast of the Lake Saimaa seal population in the year 1893 is as low as approx. 100 individuals, while the highest values are close to 1 300 animals (Fig. 2.). As a comparison, using the same methodology, the backcasted ringed seal population in the Baltic Sea in 1900 was suggested to range between 30 000 and 450 000 individuals, for the grey seal population in the Baltic the corresponding values were from 30 000 to 200 000 (V).

Based on literature, interviews of old fisherman and farmers and unpublished memorandums from field work carried out from 1966 – 1973 (Koivisto and Paasikunnas 1973), it was estimated that at the beginning of the 20<sup>th</sup> century the range of the Saimaa ringed seal covered about 90 - 95% of the area of Lake Saimaa. Towards the end of the 20<sup>th</sup> century the range had reduced to about 30 - 40% (Sipilä 1994). There was no clear observable reduction in the distribution area during the 1980's and 1990's although observations of straggler seals were made in the 1990's, e.g., in Lake Puruvesi. However, there have been no observations of birth lairs in the southernmost lairing occurrence of Lake Ilkonselkä (since the early 1980's) and of the northernmost occurrence Lake Pyhäselkä (since the mid 1990's).

*Monitoring of the population*

To reach estimates on the size of the population of the Saimaa ringed seal various census methods were applied. Seals basking on the ice during the moulting season in late April - early May were located and counted by aerial surveys. Airborne censuses were made over 114 hours in the years 1980 - 84 and for 27, 4 and 12 hours in the years 1985, 1990 and 1995, respectively (see III). Lair counting in late April and early May was made annually from 1981 to 2000. Data from aerial surveys, lair mappings and observations made by volunteers and, in some cases by local people, were also used to produce an annual estimate of the total number of seals (III). Later in the 1990's the estimation of population size was mainly based on an annual lair counting based on the assumption that each seal digs at least one lair per year. Typically, ringed seals often also have so called escape lairs, and they may use 1 - 4 lairs during a winter (Smith and Stirling 1978, Kelly *et al.* 1986, Kelly and Quakenbush 1990). It was assumed that on average a lairsite of a non-breeding Saimaa ringed seal is a circle of water area with a radius of approx. 500 m including all the shorelines inside this area. If more than one lair was detected inside this area they were classified as escape lairs of the same seal. Some exceptions were made mainly due to the visual observations of seals in small areas of an exceptionally high density of lairs.

Annual numbers of pups born were directly based on the observed number of birth lair complexes, and on the numbers of still-born pups, supplemented with visually located pups in some cases (I, III). If two or more birth lairs were found within a range of less than two kilometres from each other they were expounded as part of one birth lair complex (counted as one pup), unless two placentas were found or two pups were observed at the same time on the ice near the birth lair complex (counted as two pups). In a few cases heavy metal analyses made from the lanugo hair picked up from such nearby birth lairs suggested that lanugos originated from two different pups (cf., Lydersen and Hammill 1993a, Hyvärinen and Sipilä 1984, IV). Breeding site fidelity of the seal together with the scattered distribution in the labyrinthine lake basin (Koskela *et al.* 2002, I, III) of the population render it possible to make a rough estimate of the number of mature females breeding annually and the birth rate of mature females. When a birth lair complex was found it was counted as a lair site of a mature female. If this particular female was found dead later on, or if there were no pups observed in that particular birth lair site in three consecutive years, the mature female (or lairsite) was excluded from the list of known mature females. Taking into account the precise nature of the data based on annual lair counting, it is possible to estimate the total amount of pups born annually.

During the period 1977 - 2000 252 dead seals altogether were collected in the Lake Saimaa region. In the years 1981- 2000 bodies were collected for studies by the University of Joensuu or the Natural Heritage Services of Metsähallitus. Previously the Finnish Museum of Natural History of the University of Helsinki and the National Veterinary and Food Research Institute (EELA) also collected some dead seal bodies. The age of a dead seal was determined from canine teeth (e.g., Smith 1973a). The cause of death was determined by autopsy of 182 bodies by specialists from the EELA. Several measurements were made of the carcasses; when possible sex, weight, length etc. was determined and tissue samples were taken for further studies of concentrations of environmental toxins and for DNA-studies (III, IV).

*Present status of the population*

The bulk of the population is found in the central parts of Lake Saimaa in Lake Haukivesi and in Lake Pihlajavesi, where about 50% of individuals reside. Lakes Haukivesi and Pihlajavesi are both large water bodies (approx. 500 km<sup>2</sup>) and at present together comprise more than 50% of the undisturbed breeding habitat for the ringed seal (Table 1).

**Table 1.** *Estimated numbers of Saimaa ringed seals in the early winter 1984, 1990, 1995 and 2000 in different parts of the Lake. These figures do not include pups born in the estimation year. (see Table 2, III). (Sources: I, Sipilä 1991, 1992, updated information.)*

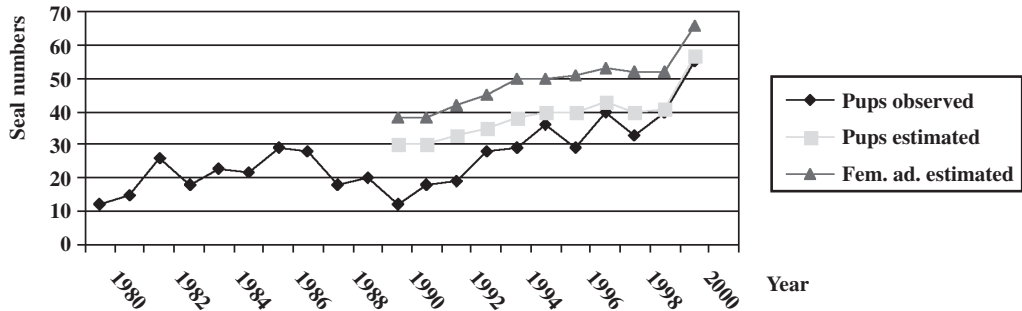
Area	1984	1990	1995	2000
Pyhäselkä	13	13	8-10	3-5
Orivesi	9-10	13-15	11-15	10-14
Pyyvesi - Enonvesi	6-7	5-8	6-8	15-18
Joutenvesi	8-10	13-18	13-18	20-30
Kolovesi	5-6	13-16	13-16	22-28
Haukivesi	32-37	41-55	44-54	48-58
Pihlajavesi	14-19	35-40	40-46	55-65
Tolvanselkä - Katosselkä	4-5	13-19	15-25	16-24
Lietvesi	8-9	13-16	8-12	7-10
Luonteri	1-2	2	2	2
Petranselkä	9-12	3-4	4-7	11-15
Ilkonselkä	4	4	3-4	2-3
Lake Saimaa in total	113-134	164-210	167-217	211-272

The division of Lake Saimaa into sub-areas is only practical for the monitoring of the ringed seal population, and is based on the geographical morphology of the lake (Table 1, III). The splitting of the lake into different areas does not suggest separate subpopulations. These areas are thought to refer to the different breeding or lairing occurrences, or even more simply to the different breeding areas of the Saimaa ringed seal.

Airborne censuses in 1995 were based on the assumption of uniform distribution of the seals on the ice, and on the assumption that 50% of the seals present were observed basking on the ice (Finley 1979, Smith and Hammil 1981, Järvinen and Sipilä 1992). This would give 42 seals in Lake Joutenvesi, 18 in Lake Kolovesi, 57 in Lake Haukivesi and 54 in Lake Pihlajavesi. These figures are probably overestimates due to the scattered distribution of seals in the lake.

At present nearly 60% of pups born annually are to be observed in the middle parts of Lake Saimaa, Lakes Haukivesi and Pihlajavesi. In the early 1980's the pregnancy rate of the Saimaa ringed seal population was approx. 70% (estimated by using the amount of pups found from known birthlair sites, III) and later on it was estimated to be 69% in 1989 - 1991, 83% in 1992 - 1994, 75% in 1995 - 1997 and 77% in 1998 - 2000 calculated as numbers of estimated numbers of pups born vs. estimated total numbers of mature females. The mean pregnancy rate in the breeding occurrence also varied in different areas of Lake Saimaa during the study period, in Lake Lietvesi our estimate was 58%, while it was 80% in Lake Kolovesi. The overall reproduction rate of the population (estimated number of pups born vs. estimated mean

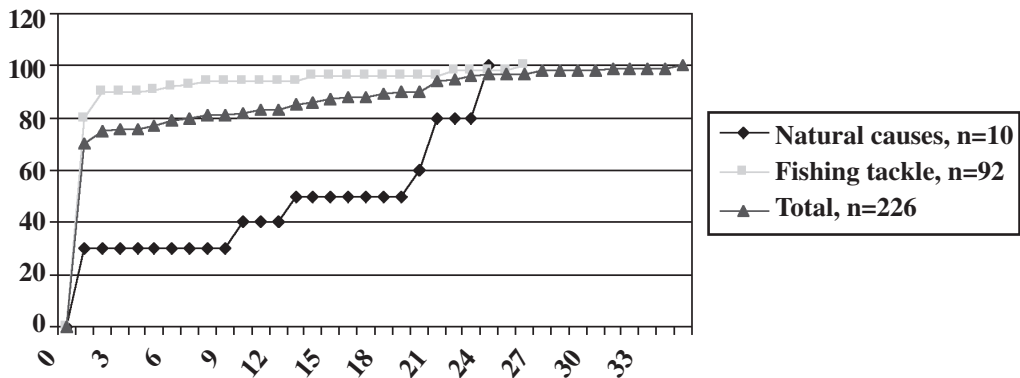
population size) for the Saimaa ringed seal population was estimated to be approx. 15 % in the early 1980's (III), and for the later periods the corresponding figures were approx. 16% in 1990, approx. 21% in 1995 and approx. 24 % in the year 2000. The increase in annual pup production (Fig. 3) also suggests an increasing total seal population. From the conservation point of view, it is promising that the observed numbers of pups were 54 both in 2001 and 2002.



**Fig. 3.** Annually observed pups in the years 1980-2000 and estimated number of pups born and mature females in the Saimaa ringed seal population.

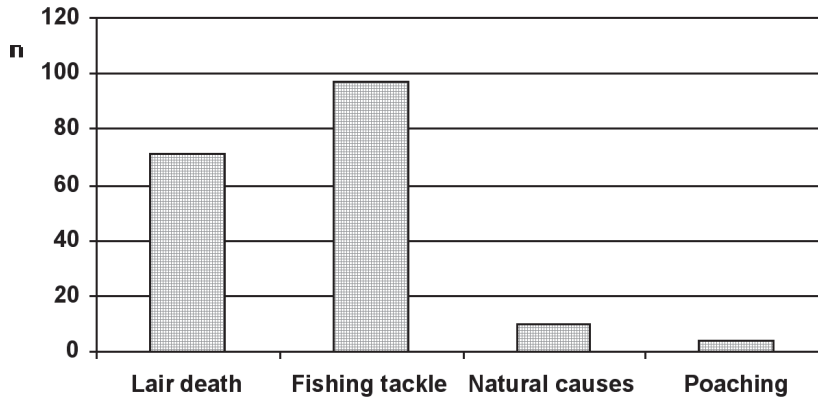
### Mortality

Observed mortality in the Saimaa ringed seal population refers to young seals, white coat or a few months old pups (I, III, IV, VI, VII). There is a large gap between cumulative mortality of yearlings due to “natural” causes or due to fishing tackle (Fig 4).



**Fig. 4.** Cumulative observed mortality (%) for various year classes of Saimaa ringed seals in 1997-1998. Note that “natural” causes do not include lanugo coated pups found dead.

For the period 1977 – 2000 the data available of 182 carcasses allowed classification of the cause of death. The most common causes of death of ringed seal in Lake Saimaa were drowning (or suffocation) in fishing tackle (53.3%) and mortality of lanugo coated pups (39.0 %). Only 5.5 % died a “natural” death (lanugo coated pups excluded), e.g., due to infections (Fig 5).



**Fig. 5.** Main causes of death of the Saimaa ringed seal 1977-2000. “Lair death” includes prematures, still-borns and accidental death of lanugo coated pups, “fishing tackle” also includes deaths from suffocation without direct evidence of contact with fishing tackle. “Natural causes” does not include lanugo coated pups found dead.

Lair mortality of lanugo coated pups is relatively high in Lake Saimaa, being approx. 20% in the early 1980’s (I, III). During 1980 - 2000 we observed a total of 550 pups and 12.9% of those were stillborn or had died, mainly from reasons unknown to us, before reaching the age of about 2 weeks (Fig. 3, 5).

Probably, the small size of ringed seal pups makes them vulnerable to various hazards in lairing conditions. Exact determination of the size of new-born pups is difficult, because normally pups are born inside the lair and thus invisible to humans. In Lake Saimaa, pups are born in late February or early March. Pup carcasses from lairs were collected in late April. In this study in all cases where we suspected that a pup had been born prematurely the individual was not included in the data set used for estimates of birth weight, but regarded still-born.

The mean weight of a new-born Saimaa ringed seal was 4.7 kg. The lightest new born pup was 3.3 kg and the heaviest 7.3 kg observed in the period 1980 – 1999 (Table 2). Low birth mass is typical of ringed seals. The mean mass of new-born Arctic Sea and Okhots Sea ringed seals varies from 3.5 kg to 5.4 kg and the mean length is 55-65 cm (Chapskii 1940, McLaren 1958, Fedoseev 1964, 1975, Hammill *et al.* 1991, Lydersen *et al.* 1992, Belikov and Boltunov 1998, Kingsley 1998).

Ringed seal pups develop a layer of subcutaneous fat during the nursing period (Tormosov and Filatov 1979, Taugbøl 1984, Lydersen and Hammill 1993b, Kelly 1988) and the premature and still-born pups found in Lake Saimaa do not have any subcutaneous blubber (Table 2). The premature pups in Lake Saimaa were about same size as full term foetuses of Arctic ringed seals (McLaren 1958, Smith 1987).

**Table 2.** *The length, weight and maximum blubber thickness on the belly side of lanugo coated pups in 1980 - 1999. A pup was determined as premature by the specialists at EELA mainly if the weight was less than 3.5 kg and/or the lungs were not open. The pups were determined as still-born when lungs were mostly only partially opened and milk was not found in the stomach. Fresh remains of umbilical cords were found on prematures and stillborns. The lungs of pups found dead in lairs (lair death) were open entirely through the onset of respiration and milk was found in the stomach.*

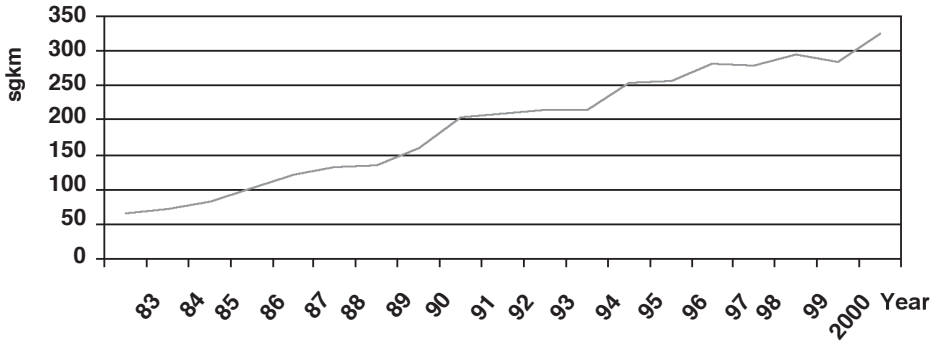
	<b>Age</b>	<b>n</b>	<b>Mean</b>	<b>SD</b>	<b>Min.</b>	<b>Max.</b>
<b>Length</b>	Premature	4	57.00 cm	3.37	53 cm	61 cm
	Still-born	11	64.36 cm	6.55	48 cm	72 cm
	Lair death	17	66.94 cm	5.25	53 cm	74 cm
<b>Weight</b>	Premature	7	2.61 kg	0.72	1.3 kg	3.3 kg
	Still-born	9	4.70 kg	1.29	3.3 kg	7.3 kg
	Lair death	17	5.84 kg	1.11	3.6 kg	8.1 kg
<b>Blubber</b>	Premature	3	0.0 cm	0.0	.0 cm	.0 cm
	Still-born	7	0.0 cm	0.0	.0 cm	.0 cm
	Lair death	17	0.8 cm	0.68	.0 cm	2.8 cm

Occasionally, the water level in Lake Saimaa sinks or rises during winter due to natural causes or due to regulation procedures by the authorities. The water-level change breaks down the ice sheet near the shorelines (Sipilä 1988, 1989, Sipilä and Hyvärinen 1989, I, III, VII). In the years 1982, 1983, 1988, 1989 and 1996 a numbers of lairs collapsed in mid winter due to abnormally high variation in the water level. In these years, on average 31% of the observed pups were found dead in lairs. In contrast during the winters 1980 - 2000 when water level during the lairing period was kept roughly stable, the percentage of pups found dead in lairs was 8.4 %.

The instability of lairing conditions in Lake Saimaa area for the ringed seal also affects lactation. It has been shown that in years with high variation in water level during the lactation period, the weaning mass of pups is lower than in winters with more stable water levels (Becker 1984, Sipilä 1988, 1989, Sipilä and Hyvärinen 1989). This also increases the hazard to the first independent steps of the pups, as pups in less good condition get more easily fatally entangled in fishing tackle than pups in better condition (Becker 1984, Sipilä and Hyvärinen 1998).

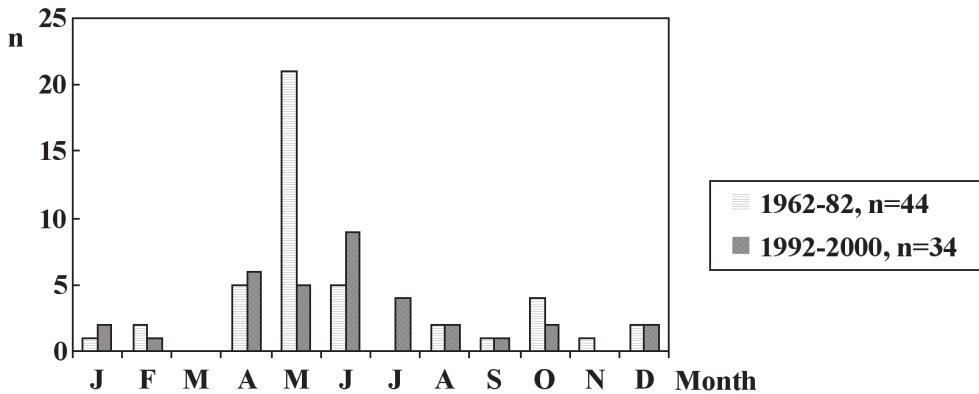
Various fishing tackle has turned out to be mortal traps for the Saimaa ringed seal, especially for the young and inexperienced ones. Therefore, as an overall management action, fishing restrictions from mid April to the end of June in major breeding areas of the Saimaa ringed seal were introduced to prevent the drowning of seals in fishing tackle (Fig. 6) (Sipilä 1991, 1992, Sipilä and Hyvärinen 1998, III).





**Fig. 6.** The total surface area of fishing restrictions area in Lake Saimaa between the dates of 15.4 –30.6 has gradually increased from 65 km<sup>2</sup> in 1982 to 326 km<sup>2</sup> in 2000.

The extant data (1962 – 1984,  $n = 44$ ) on seasonal mortality of seals less than one year of age, fatally entangled in various fishing tackle, shows that 71% died in April – June. The corresponding figure for, 1992 – 2000 ( $n = 34$ ) is 59 %. This data (Fig. 7) clearly indicates that there is a critical period after weaning when young inexperienced pups face a considerable risk of death due to human fishing activities.

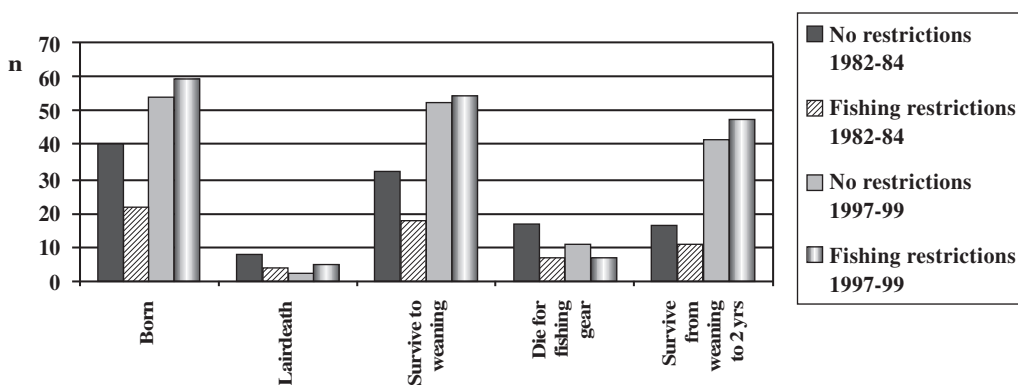


**Fig. 7.** Monthly distribution of young seals (< one year in age) that have become fatally entangled in various fishing tackle in 1962 - 1982 and in 1992 - 2000. (Hyvärinen and Sipilä 1983, updated information).

The survival rate of weaned pups to the age of two years is approx. 10% higher in the fishing restriction areas than in areas without restrictions (Fig. 8. see also Table 7 in III). The difference is small, but in the long run it may turn out to be a significant factor contributing to the rise of the ringed seal population size in Lake Saimaa. The fishing restrictions were primarily established in the areas where intensive net fishing was carried out. In the early

1980's 40% of pups born in protected areas were drowned in fishing tackle while before implementing the restrictions up to 60% of pups born alive perished (III). No similar estimate concerning improved survival in fishing restriction areas in the late 1990's is available.

In years 1982 - 1984 about 40% of pups that survived the suckling period in the protected areas perished, while 50% of weaned pups died in non-protected areas. In the late 1990's comparable figures are 13% in protected areas and 21% outside those areas (Fig.8, cf. Table 7 in III). In the years 1982 - 1984 38% of all pups born were born inside areas with fishing restrictions (approx. 74 km<sup>2</sup>), compared with 52% for the years 1997 - 1999, when the restricted areas encompassed approx. 285 km<sup>2</sup>.



**Fig. 8.** Fate of Saimaa ringed seals pups up to the age of two years in areas where net fishing has been forbidden April 15 – June 30, compared with areas without restrictions in 1982-1984 and in 1997-1999. (“Lairdeath” includes also prematures and still-borns; III, updated information).

### *Mercury and the Saimaa ringed seal*

It was seen as relevant, especially in knowing how intensive the pulp industry (the source of mercury in fresh waters, together with forestry and peat-land ditching) has been, and still is, in the region of Lake Saimaa, to assess mercury levels in tissues of the Saimaa ringed seal. Analyses of mercury concentration were performed from tissue material obtained from carcasses found in the area. We also used lanugo hair collected from birth lairs. Analyses of mercury concentrations were undertaken at the Department of Biology, at the University of Joensuu.

A substantial reduction in tissue mercury levels from the early 1980's to the first half of the 1990's was seen in muscle samples of seals one to six months of age. A matching reduction in mercury contamination of the liver was also evident in seals of three months of age during the same period of time. However, in striking contrast, mercury concentrations in liver and muscle tissues of seals less than one month of age, as well as in lanugo hair of pups did not show any observable change in the period from 1981 to 1995. Our data also show that in the liver tissue of adult seals, mercury levels remained more or less unchanged during the study period (IV).

In these studies we found a clear positive correlation between seal age and mercury concentration. This data shows that the mean accumulation rate of mercury in the liver of the Saimaa ringed seal is approx.  $11 \text{ mg yr}^{-1}$ . About 80% of the total mercury accumulated in adult seals was stored in their liver, while the rest was found mainly in the muscles. In an age group of seals of approximately 3 months old in the early 1980s, some 75% of the total mercury accumulated in the body was found in the muscle tissues, and the corresponding value for the early 1990's was 65 %. An interesting finding is that in this age group mercury concentration in the liver increased from 20% to 30% during the same time period. In an experimental study it was found that selenium in the diet of an adult seal reduced mercury concentrations in hair. It is also noteworthy that when this experimental seal was released back to its native habitat, the level of mercury in hair soon increased back to the initial level (IV).

#### *Demographic effective population size and estimated extinction probabilities*

Applying the new methodology (Kokko and Ebenhard 1996) for the Saimaa ringed seals showed that the estimated probability for population extinction decreased when the demographically effective population size,  $N_D$ , increased. Our research showed that, practically speaking, the Saimaa ringed seal population would be safe from extinction due to reasons associated with demographic stochasticity if  $N_D$  is about 100 or more. Unfortunately, this “number safe haven” will have a heavy inflation once the target population is split into age groups of two sexes distributed in a network of a labyrinthine lake system. The future presence of the Saimaa ringed seal in the lake complex is very dependent on the age-structure, reproductive success and dispersal-linkage between the different sub-regions (VI). Subtle changes, e.g., annual reproduction success, may yet, with these low individual numbers, tip the balance in unfavourably to the long-time persistence of the population. Thus, care has to be taken to manage the seal population to sustain it on the current track of positive growth rate.

#### *Legal status and guidelines for Saimaa ringed seal protection*

The Saimaa ringed seal population was listed as a game population in Finnish legislation until 1993. In that year legal protection of this endangered population was transferred to the Nature Conservation Act, and the responsibility for management was given to the Ministry of Environment and in practice to the Natural Heritage Services of Metsähallitus. Actually accession of Finland to the European Union, in 1995, led to a comprehensive renewal of the Finnish Nature Conservation Act in 1996 (Kallio 2001, VII).

The Finnish National Shoreline Conservation Programme was approved by the Council of State in December 1990. This programme is solely focused on protecting shorelines rimming lakes and the Baltic Sea. However, it also gives the means to protect the breeding habitat of the Saimaa ringed seal. The state is prepared to grant nature protection to the areas covering the lair sites which were proved to be used by ringed seals. The usage of the lair sites should be verified by separate studies (Anonymous 1991). This clause foreshadowed the Natura 2000 program. The Finnish Shoreline Conservation Programme covers approx. 70% and the Natura 2000 program covers approx. 95% of the shorelines where the Saimaa ringed seals lair sites are located. The shorelines in the present national parks cover some 34% of birth lair sites and approx. 24% of haul-out lair sites. Outside the Natura 2000 program areas, the Act Concerning

the Planning and Construction of Buildings limit the number of buildings on the shoreline to 3 - 7 per kilometre (Sipilä and Koskela 2000, VII).

The Habitat Directive also requires that incidental killing should be limited if it causes a significant threat to strictly protected species, included in Annex IV(a) of the Habitat Directive (VII). Some modern fishing methods, e.g. strong-mesh-gill nets, fish baited hooks and salmon traps can even kill adult seals throughout the year. The present norm, based on the Fishing Act, only forbids some fishing methods which can kill adult seals, and only inside Natura 2000 areas (Sipilä and Koskela 2000, VII).

The Act concerning water level regulation of Lake Saimaa was renewed in 1991 to reduce mortality of lanugo coated pups. Under the legislation regulating motor vehicle use on the ice of the lake disturbance of lairs by snowmobiles can also be eliminated. These protection methods based on two separate Acts are not traditionally included in management plans of the protected areas (VII).

The demands of the Habitat Directive were taken, partly in an incomplete form, into consideration in protection of seal populations in the European Union. The protection of the critically endangered Mediterranean monk seal is now implemented in practice. In the Mediterranean, European Union countries and Turkey national laws to protect the Mediterranean monk seal have been introduced. Despite the legislation, deliberate killing of monk seals still occurs in some Mediterranean areas and the habitat protection in Greece and Turkey only encompasses coastal waters although the monk seal routinely range distances of over 65 up to 160 nautical miles (e.g. Admantopoulou *et al.* 1999, VII). In Britain both legal and illegal killing of grey and harbour seals is widespread, partly even in protected areas. In the case of protection of “lower risk” seal stocks in Britain the legislation is quite undeveloped (VII).

## General discussion

### *Breeding in lair*

The Saimaa ringed seal has had to adapt to exceptional circumstances in the labyrinthine water course of Lake Saimaa, e.g. the only places where snow piles up are the shorelines. The shoreline lairs are vulnerable to changes in water level during the lairing season (the relatively narrow ice “belt” where snow piles up is confined to the shoreline, when the ice sheet forms on the lake) and man made disturbance and land-predators (I).

The Saimaa ringed seal shoreline breeding habitat on rocky shorelines sufficiently resembles ringed seal ridged fast ice breeding habitat elsewhere (e.g. McLaren 1958, Fedoseev 1975, Smith 1975, Kelly 1988, I). A similar breeding habitat of ringed seal was also found in the northern part of Lake Ladoga (Sipilä *et al.* 1993, 1996, 2002, Kunnasranta *et al.* 2001).

In Lake Saimaa the lair offers shelter against a harsh winter climate and predators, and breeding inside a lair is essential for this freshwater subspecies of the ringed seal to survive (Smith and Stirling 1975, Stirling and McEwan 1975, Gjertz and Lydersen 1983, Sipilä 1987, 1988, 1989, 1997, Lydersen 1998, Kelly 2001, I, II, III). In Lake Saimaa there are only two docu-

mented cases where a white coated pup has been found on open ice without the shelter of a lair. One of the pups survived through the whole lactation period, while the other one starved to death. These observations underline the significance of the lair for successful breeding of the endangered Saimaa ringed seal.

It is documented that ringed seals tend to avoid risks of predator hazards when selecting lair sites (e.g. McLaren 1958, Smith and Hammill 1981). Potential seal predators in the Lake Saimaa area are red fox (*Vulpes vulpes*), wolf (*Canis lupus*), brown bear (*Ursus arctos*), lynx (*Lynx lynx*) and also in some locations wolverine (*Gulo gulo*). Sometimes, in April one finds small tunnels, most likely made by mink (*Mustela vison*) leading to lairs. Red foxes or dogs sometimes have “marked” by slightly digging into the snowroof of a few lairs, but there are no records that they have broken the roofs of lairs in Lake Saimaa. There is only one observation (Lake Kolovesi, March 1, 1991) that two dogs or two red foxes had attacked a birth lair and killed a new-born pup. Later in spring 1991, also in Lake Kolovesi during lair studies, remains of two other pups were found as an indication of death in their lairs. Those pups were partially eaten, and at least one of them with subcutaneous blubber had died during the lactation period. The small body size of white coated ringed seal pups makes them potentially vulnerable to avian predators such as the glaucous gull (*Larus hyperboreaus*) and raven (*Corvus corax*) (Lydersen and Smith 1989, Kelly 2001). Herring gulls (*L. argentatus*) and hooded crows (*C. corone*) are seen to disturb adult seals basking on the ice in April during their moulting season (Järvinen and Sipilä 1992), but these are mainly a nuisance.

#### *Variation in population size*

Official bag statistics probably do not include all the kills of any target population. Thus, in our backcasting studies the scenario of “assumed kills” may reflect reality better than annual numbers of bounties paid (Fig.2). It is also presumable that the recorded bounty statistic does not carry the whole truth of the population decline. The estimation for the population size in 1893 remains below 1000 seals, even whit a regulatory role for density dependence. This may indicate that at the end of the 19<sup>th</sup> century the Saimaa ringed seal population was smaller than generally anticipated. Still the population size at that time may well have been about four times larger than at present (V). According to Reeves (1998) and Harding and Härkönen (1999) the maximum growth rate of the ringed seal population can not exceed 1.15. We certainly more or less also used too high growth rate (1.15) when backcasting Saimaa ringed seal population size and our minimum estimate of approx. 100 seals in year 1893 is too low (Fig. 2, 9a,b) (Härkönen, pers, comm.).

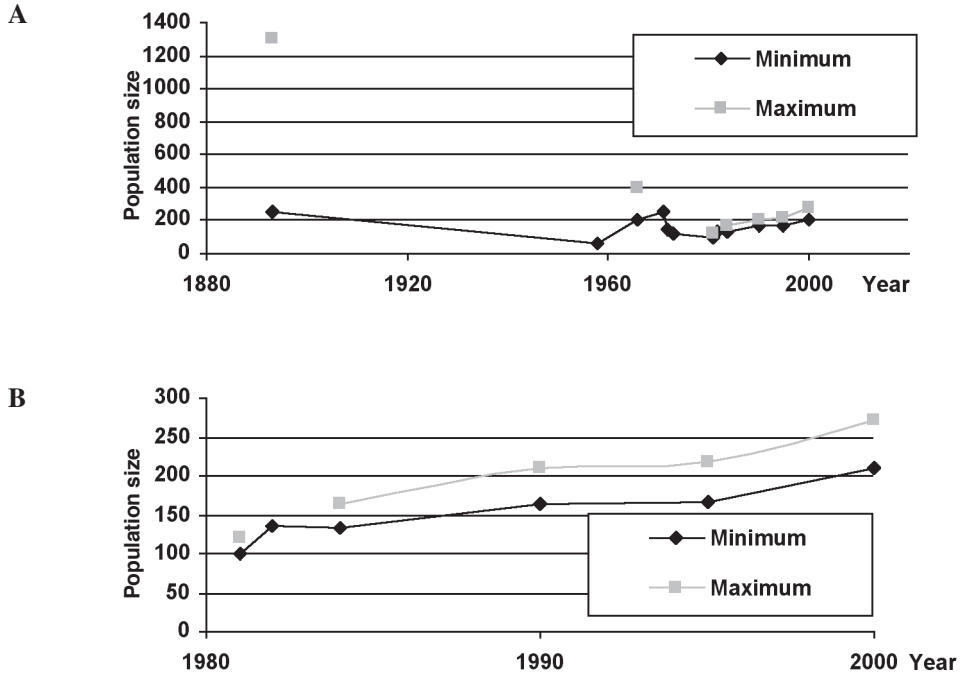
In contrast to Lake Saimaa, the Baltic Sea seal populations have decreased drastically, even the worst scenarios in the backcasting procedure give approximately ten times larger population sizes at the beginning of 20<sup>th</sup> century than at present. Hunting has surely had a notable effect on Baltic seal populations (Bergman 1958, Helle 1979, Harding and Härkönen 1999, V). Very probably Ladoga ringed seal population size has also decreased approx. 50 - 75% during the 20<sup>th</sup> century and most likely mainly due to hunting (Chapskii 1932, Jääskeläinen 1942, Sipilä *et al.* 1996, 2002, Sipilä and Hyvärinen 1998). Generally in the European Union the distribution area and size of many seal populations have diminished during the 20<sup>th</sup> century. This is to the extent that at present mainly only stray seals can be found in Spain and Italy (IUCN 1996, Brasseur *et al.* 1997, Reeves *et al.* 1992, VII).

Exceptionally the monitoring of the Saimaa ringed seal population is largely based on the counting of total population size and annual total pup production. Airborne censusing is a typical method to estimate sizes of ringed seal stocks in the Arctic Ocean, the Baltic Sea and Lake Ladoga. However, airborne censusing alone is not adequate to estimate sizes of a small and scattered seal population such as that in Lake Saimaa (Smith 1973b, Antoniuk 1975, Nikkari 1975, Finley 1979, Helle 1980a, 1986, Harwood and Stirling 1991, Kelly 1988, Härkönen *et al.* 1998, III). The data from airborne censuses supplemented with data of observed lairs and other observations of seals basking on ice give more reliable population estimates. For the Saimaa ringed seal, estimation of the population size is mainly based on annual lair studies. This is especially true for the 1990's.

Efficiency of lair counting varies annually and spatially (Fig 1.). Its efficacy is influenced by various circumstances, e.g., weather, ice conditions, amount of snow, technical equipment for moving on the thin ice, time and financial resources and even the experience of persons participating in the censuses. Annual lair counting in the 1990s covered about 60 - 90% of known lairing or breeding areas. In late April lair counting is focused on finding birth lairs. Large birth lair complexes are also easier to find than smaller haul-out lairs. Thus, many factors have to be taken into account when reporting annual seal numbers. These include, among many other things, long-term information of lairing site usage and observations of seal mortality. This mainly explains the range given by annual estimates (Table 1).

Adult Saimaa ringed seals generally exhibit a high degree of site fidelity and have a fairly small home range, with movements covering normally only a few kilometres (Koskela *et al.* 1996, 2002, Hyvärinen *et al.* 1999a,b). Due to this fact, and due to the simple fact that many hundreds of kilometres of shorelines compose the breeding areas, the lair counting method (I, III) itself gives better data year after year. This is because the amount of data accumulated on the use of particular lairing sites serves as first-hand guidance for focusing lair counting in the next year to come. Therefore, even in the late 1990's the lair studies were slightly more reliable than in the early 1990's (Table 1, Fig. 1, 3, 9).

Probably, the size of the Lake Saimaa seal stock decreased substantially in the mid 1950's. When hunting was stopped a latent period for the recovery might have prevailed. In the late 1960's, the population size probably started to decline again as a consequence of new fishing methods and maybe environmental toxins such as mercury also had an affect on the population size (Marttinen 1946, Sipilä 1981, Becker 1984, Hyvärinen and Sipilä 1983, 1984, I, III, IV). The estimates of the Saimaa ringed seal population size in the 1980's were most likely underestimated, due to the inadequate data (Helle *et al.* 1981, Sipilä 1983, III). The first reasonably reliable estimate is from the year 1990, when about 180-200 seals were estimated (Table 1, Fig. 1, 3, 9).



**Fig. 9a,b.**

Minimum and maximum estimates for the Saimaa ringed seal population (A) in the long term (1893-2000) and (B) in the short term (1981-2000). (Sources: Bergman 1958, Haapanen 1966, Koi-visto 1972, Koivisto and Paasikunnas 1973, Nikkari 1975, Helle et al. 1981, Sipilä 1983, III, updated information; supplemented Nikkari pers. comm., Koivisto pers. comm. and Härkönen pers. comm).

In the late 1990's the seal stock had increased by about 50 animals (Table 1, Fig.3, 9), corresponding to an annual growth rate of approx. 1.04 (Sipilä and Koskela 2001a). The improved accuracy in the late 1990's in the lair counting method explains some 25% of the observed growth of population size in the late 1990's (Table 1, Fig. 1). Present growth rate is definitely smaller than the possible maximum rate for the ringed seal population (Reeves 1998) but it is substantially greater than 1.01 which was the earlier estimate for the years 1977 - 1995 (VI).

#### *Distribution and local population density*

One alarming feature of the Saimaa ringed seal population is that there are seven breeding or lairing occurrences open lake areas, with less than 20 seals (Table 1). Lairing areas in lakes Ilkonselkä and Luonteri are those where annually only a few seal are recorded and these may be stray individuals from nearby stronger breeding occurrences. Due to immigration even a small population can recover and hence the minimum viable population size is always a case-specific concept and the idea of “minimum” suggests that there are critical aspects of the “population-in-its-environment” (Gilpin and Soulé 1986). The Lake Pyhäselkä population may vanish in the near future and this extirpation will greatly reduce the distribution range of the

Saimaa ringed seal. This suggests that critical conditions in the environment of the seal have already changed too much in Lake Pyhäselkä. Hence, it is likely that in this lake, we do not have any management means to reverse the condition of the environment suitable for the seals in Lake Pyhäselkä (Sipilä 1991, I, III, VI, VII). In contrast, in Lake Petranselkä the seal stock recovered in the late 1990's, presumably due to seals originating from nearby Lake Lietvesi. As an experiment a mature female was transported from Lake Haukivesi to Lake Lietvesi in 1992. She was observed in Lake Petranselkä over a period of two weeks and for the first time she gave birth to a pup there in 1994 (Hyvärinen *et al.* 1995).

Over the study years, the most promising population increase (approx. 40%) was found in Lake Kolovesi, a 25 km<sup>2</sup> lake (Table 1). In this area annual pup production rose during the past decade from 3 to 4. Since the mid 1980's Lake Kolovesi has been nearly totally encompassed by fishing restrictions between the 15 April and the end of June. Lake Kolovesi is included in the National Shoreline Conservation Program, and in 1990 the Finnish State founded the Kolovesi national park. Even the use of motorboats is forbidden on this lake, which probably also decreases the amount of fishing tackle used in Lake Kolovesi.

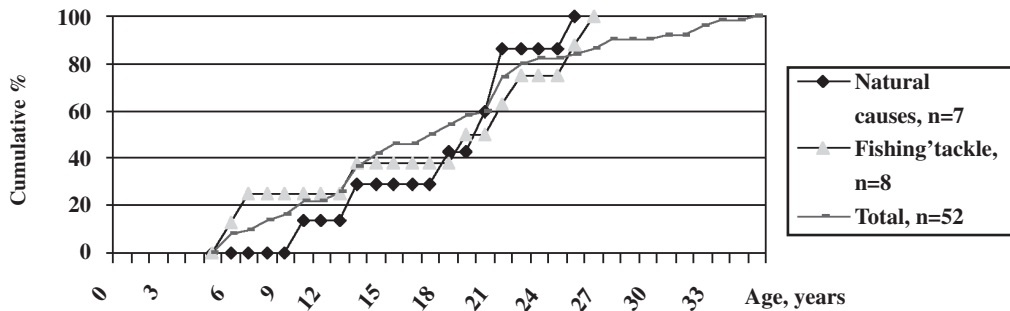
The mean distance along water routes between the Saimaa ringed seal birth lairs is 5.5 km, which is longer than the mean distance between haul-out lairs, 1.2 km, (data from lakes Kolovesi, Joutenvesi, Haukivesi and Pihlajavesi, 1986 – 1988; Sipilä 1992, Sipilä and Hyvärinen 1998). In Northwest Canada the mean distances between ringed seal birth lairs over the years in different locations ranges from 300 m to 800 m. In the other types of lairs distance ranged between 124 m to 800 m (Smith and Stirling 1975, 1978). At Kongsfjorden in Svaldbard the mean distance between the birth lairs was 500 m and between tiggak lairs (rutting male lairs) 600 m (Lydersen and Gjertz 1984). Based on field observations in the Lake Saimaa area, the long distance between birth lairs is not due to lack of suitable snowdrift formations; and hence no good evidence exists to explain the lengthy distances.

Geographically, estimates of ringed seal population densities varies from 0.12 to 3.5 seals per km<sup>2</sup> (Reeves 1998). The present distribution of the Saimaa ringed seal gives an allusion of a density of 0.1 seals km<sup>2</sup>. The highest density of 0.88 - 1.12 km<sup>2</sup> is found at present in Lake Kolovesi. The population size of Lake Saimaa in pristine state was assumed to be at least 2000 - 2500 seals (Hyvärinen and Sipilä 1992). An extrapolation, based on Lake Kolovesi, gives a potential total population size in Lake Saimaa of about 3800 - 4900 seals. Although the carrying capacity of Lake Saimaa for ringed seal is not soundly enough scored, the backcasted maximum population size of 1300 animals in the year 1893 (V) reflecting density of approx. 0.3 seals per km<sup>2</sup> probably did not reach the carrying capacity of the lake.

### *Population structure*

The sex ratio in the Saimaa ringed seal population is 1:1, and the mean maturity age of males according to the length of the baculum is 4 + years (McLaren 1958, Sipilä *et al.* 1999). Due to lack of data having only 1 fresh sample and 4 decomposed samples of females from 4 to 8 years, the maturity age of females is unidentified. Extant mortality data suggest that the mean life span of this seal is 19 - 23 years (Fig. 10; Sipilä and Hyvärinen 1998, Sipilä *et al.* 1999, III).





**Fig. 10.** Cumulative observed mortality (%) for various year classes of adult Saimaa ringed seal in 1997-1998.

The present population age structure is probably biased, although younger aged classes are probably not as underrepresented at present as, they were earlier in the 1980's (Nazarenko 1964, McLaren 1958, Smith 1973a, Hyvärinen and Sipilä 1983, Hyvärinen *et al.* 1984, Reeves 1998, Sipilä and Hyvärinen 1998, Sipilä *et al.* 1999, III, VI). Actually approx. 66 mature females in the year 2000 (Fig. 3) corresponds to approx. 130 adult seals and approx. 110 non-breeding immature or mature seals in scattered populations (Table 1, Fig. 3).

The pregnancy rate of the Saimaa ringed seal varied from 75% to 83% in the 1990s, which roughly suggests that the breeding capacity is more or less normal. Hence there are no data to support that environmental toxins significantly affect the breeding success of this seal population (Helle 1980b, Helle *et al.* 1983, Hyvärinen and Sipilä 1984, IV).

Genetic studies suggest no spatial differentiation among seals from different parts of Lake Saimaa. However, the level of heterozygosity of the Saimaa ringed seal is 69 % lower than ringed seals in the Baltic Sea and Arctic Ocean (Palo *et al.* 2003).

#### *Decrease of mortality in fishing tackle*

If mortality of lanugo coated pups ("lair death" see Fig 5) is excluded from the sources of mortality the significance of drowning in fishing tackle rises drastically up to 87%. This underlines that fishing tackle is an acute threat to the persistence and recovery of the Saimaa ringed seal population (Sipilä *et al.* 1999, III). Very probably the mortality due to fishing tackle is higher than was observed (n = 97), because 17.5% (n = 17) of seal found dead by suffocation (fishing tackle, Fig. 5) were found by people from the shorelines and even 68.7% (n = 68) of the carcasses found on shorelines (n = 99) were too decomposed to determine the cause of death by autopsy. The annual mortality data is insufficient and together with data of the number of pups born annually gives a far too optimistic scenario for the future of the population (Fig. 3, 8).

The habitats Directive requires that incidental killing should be limited if it imposes a threat to strictly protected species [list included in Annex IV(a) of the Habitat Directive (VII)]. The springtime fishing restriction is an effective method to reduce mortality of young seals, but

still the prevention of suffocation of seals in fishing tackle is mainly based on temporary contracts between Metsähallitus and local water area owners in the Lake Saimaa area (Fig. 6, 8). Some current fishing methods can even kill adult seals throughout the year (Fig 10). Current limited data do not prove that adult mortality in fishing tackle is significantly increasing in Lake Saimaa, but suggest that more adult heavy weight seals got tangled in fishing tackle in the 1990's than previously (Sipilä and Koskela 2000). This threat to the seal population will probably increase in future and the extraordinary mortality of adult seals strongly deduces the growth rate of the population (Durant and Harwood 1992, Forcada *et al.* 1999a,b). A straight-forward conclusion is that without fishing restrictions the Saimaa ringed seal population is in great danger of extinction.

In 1996 the Finnish Parliament added a new section to the Fishing Act which gives the possibility of wider fishing limitations (Sipilä and Hyvärinen 1998, Sipilä *et al.* 1999, VII). The present norm-based Fishing Act for the period 1<sup>st</sup> May 1999 – 30<sup>th</sup> April 2004 only forbids some fishing methods, which can kill adult seals, and only inside the Natura 2000 areas and 50% of observed deaths in fishing tackle of seals heavier than 30 kg occurred outside the Natura 2000 areas (Sipilä and Koskela 2000, VII).

#### *Protection of the lair sites*

The observed site fidelity of the Saimaa ringed seal probably partly originates from the lairing behaviour. Due to landscape structures large snowdrifts form year after year on the same shorelines. There is evidence that Arctic ringed seal are territorial during the lairing season (Stirling 1977, Smith and Hammill 1981).

In late April, when roofs of lairs have collapsed, birds such as ravens, hooded crows, herring gulls and also foxes will scavenge the bodies of stillborn pups remaining in the lairs. The carcasses of the lanugo coated pups, dying between the end of February and the beginning of March, are frequently found in late April in the study area (I, III). Only in 15 cases out of 71 has the exact cause of death of these pups been determined. There is indirect evidence (e.g., broken skulls, 5 cases and internal wound in liver or lung, 4 cases) that in some cases the cause of death is due to actions taken by man. The rate of natural death of lanugo coated pups is totally unknown in the study area, but it seems that most of them are born alive and only a few were premature and some still born (Table 2, Fig. 5) (Sipilä and Hyvärinen 1998, Sipilä *et al.* 1999).

During the annual lair studies one can also collect hair samples or even seal carcasses for laboratory studies and so lair counting on the ice gives more information about the population than lair counting by remote studies e.g. by infrared camera (I, II, III, IV). The visual lair counting method with hovercrafts, snow-mobiles etc. in late April, when the roofs of the lairs have collapsed also causes disturbance, but there were not any direct observations that employed lair counting methods in late April led to seals abandoning the lair site.

It is thought that the main reason why just weaned pup's get easily tangled in fishing tackle is due to the small size of the seal (Becker 1984). In ringed seal stocks abnormally small-sized weaned pups (starvelings or stunted) were occasionally found (Helle 1983, McLaren 1958, Smith 1987). These small-sized young ringed seals in the Arctic are the consequence of abnor-

mally short suckling periods or disturbance of lairing (Lydersen and Gjertz 1987, Hammill *et al.* 1991, Lydersen *et al.* 1993). Disturbance caused a significantly lighter weaning mass of pups compared with the weaning mass of non-disturbed pups of the Southern elephant seal (*Mirounga leonina*) and pup weaning mass was positively associated with 1<sup>st</sup>-year survivorship (Engelhard *et al.* 1998, 2000).

In Lake Saimaa females give birth to their pups during a period of two to three weeks in mid February - early March. The lactation period and probably also the lair site selection period in early winter are vulnerable to various man made disturbances. This suggests that, as a Saimaa ringed seal protection strategy, lairing sites or occurrences should be protected from any human disturbance from December to late April. The National Nature Protection Act and the Habitat Directive also forbid disturbance of Saimaa ringed seal lairing.

The present situation of protection of lair sites is not satisfactory. Only in Kolovesi national park, in some islets in Linnansaari national park (in Lake Haukivesi) and a few single islands in other breeding areas, trespassing is forbidden on shorelines in wintertime.

#### *Factors of disturbance in lairing habitat*

In Lake Saimaa, mortality of lanugo coated pups is positively correlated to unstable lairing conditions due to water level changes in winter (I, III). Since 1991 the act and strategy concerning the adjustment of the water level of Lake Saimaa has changed. At present the Saimaa ringed seal habitat needs (for breeding on the shorelines) were taken into consideration in water level regulation (VII). In the period 1980 - 1991 14.5% out of 241 observed pups were found dead, while in 1992 - 2000 the figure was reduced slightly to 11.7% ( $n = 309$  pups). In 1996, when the water level in Lake Saimaa sank exceptionally in winter due to natural reasons, over 40% of pups were found dead in their lairs (Sipilä 1997). If we exclude 1996, the 1992 - 2000 mortality of lanugo coated pups was limited to 8.2%.

Man made disturbance presumably also leads to mortality of ringed seal lanugo coated pups, but at present this source of mortality can not be estimated. Disturbance of lairs by leisure snowmobiles can be eliminated under legislation regulating motor vehicle use, but no decisions have been made yet to limit the use of snowmobiles in the ringed seal breeding areas.

In the Arctic Ocean predation of ringed seal pups by arctic fox and polar bear varies from 6% to 40% (Stirling and Archibald 1977, Smith 1976, 1980, 1987, Kelly 1988, Kingsley 1998). These figures of mortality rate of lanugo-coated pups in the Arctic Ocean and in Lake Saimaa are roughly the same in magnitude, although the causes of deaths are different.

It is most likely that ringed seals in Lake Saimaa avoid areas of human disturbance, e.g., areas near the mainland and shipping lanes (III). Similar observations are also found for ringed seals in the Arctic Ocean (Alliston 1980, Kelly *et al.* 1986, 1988, Smith 1987, Reeves 1998). In the 1990's only the most important shipping lanes to paper mills were used year round in Lake Saimaa, but there are no observations that this activity has increased the mortality of lanugo coated pups. At present, use of shipping lanes in winter has probably diminished suitable breeding habitat available for the seals.

Recreational houses along lake shorelines are a constant source of disturbance, and they also permanently change the nature of shorelines outside protected areas in Lake Saimaa (Sipilä and Koskela 2000). Our data show that the number of lairs increases with increasing distance from potential sources of man made disturbances (Sipilä 1992, I). This also underlines the necessity of the protection of present lair occurrences and remaining breeding habitat in the lake complex.

### *Concentrations of mercury*

The high concentration of mercury in seal tissues in the 1960s indicates that the detoxification mechanism of the Saimaa ringed seals was not effective enough to eliminate the mercury load (IV). Nourishment in the Saimaa ringed seal differs from nourishment in ringed seals in the seas and oceans. In Lake Saimaa the lack of selenium probably sets a limit to the detoxification mechanism (Käkelä *et al.* 1995, Dietz *et al.* 1998, Kunnasranta *et al.* 1999, IV).

Mercury in natal hair indicates the passage of mercury across the placental barrier from the high concentration of mercury in the blood of pregnant females (Hyvärinen and Sipilä 1984). The main tissue where mercury may be derived from milk was muscle (IV). Medvedev *et al.* (1997) assume that the mercury load is lower in old ringed seal females than in old males. Today the Saimaa ringed seal pups receive much less highly toxic methyl mercury during the nursing period than in the early 1980s. Notably the concentrations of mercury in muscles of weaned pups have decreased strongly. The relative proportion of mercury in the muscles compared to mercury in the liver has also decreased (IV). In a similar manner, in Lake Ladoga mercury concentrations of adult ringed seal hair had decreased in the late 1990's (Medvedev *et al.* 1997, 2001). The general conclusion is that very probably at present environmental toxins, not even mercury have any significant affect to the well being of Lake Saimaa seals.

### *Aspects of the management of the Saimaa ringed seal population*

A small population of long life span animals can survive a relatively long time (Vermeij 1985, Culver 1986, Williams and Nowak 1986), and in Lake Saimaa the habitat availability and conditions for survival of ringed seal have been better in the past than at present. This may explain how the Saimaa ringed seal has persisted so long as an isolated population in Lake Saimaa (VI). It should be noted that the present small recovery in numbers does not automatically forecast a safe future for the Saimaa ringed seal population.

Presumably nearly all the shorelines outside protected areas will be an unsuitable breeding habitat for the Saimaa ringed seal in the future (Sipilä 1991, Sipilä and Pelkonen 1994, Anonymous 1995, Sipilä and Koskela 2000, 2001b, III, VI, VII). In future, icebreaking and regular use of the shipping lanes in winter could expand due to planned prolongation of the sailing season (at present normally from April to December) on the existing Saimaa canal and also due to an idea to build a new and larger channel to and from Lake Saimaa via Kymijoki to the Baltic Sea. The growing amount of recreational houses on the shorelines will impose yet another increasing disturbance threat to the seals. If the Saimaa ringed seal will face extinction, it will probably be caused by changes in the environment, not by genetic problems e.g. inbreeding (Järvinen and Varvio 1986, Järvinen and Miettinen 1996, Hartman *et al.* 2001, Palo *et al.* 2003).

For a successful conservation of the Saimaa ringed seal, reliable population data (including births and deaths) are needed. Collection of such data should be carried out annually to render management action feasible (Ranta *et al.* 1996). The Saimaa ringed seal population must still be considered vulnerable to extinction due to reasons of demographic stochasticity alone. The number of individuals alone is an insufficient measure of the population status. For conservation management we need data on the spatial distribution and on local population structures. The study of demographic effective population size underlines the importance of assessing the population size and (age) structure (VI). Ideally, extinction risk should be as close to zero as possible. The juridical practice concerning the favourable state of conservation in Finland has just become established (Koskela *et al.* 1999, Kallio 2001), now it remains to be implemented in practice.

An ecological risk analysis of the endangered Saimaa ringed seal population, based on the exponential growth model, shows that neither the wintertime water level changes, or mortality in fishing tackle alone increases the risk of extinction to an intolerable level. However, in combination they may be fatal (Ranta *et al.* 1996). The scattered spatial structure of the Lake Saimaa ringed seal population (I, III, IV) might pose a threat to the long-term persistence of the population. The value of  $N_D$  responds strongly to the changes in life table characteristics (VI), which, in turn can easily be altered by reducing external mortality (drowning in fishing tackle) by young seals.

The various risk analyses support the fact that the present protection activities are suitable to prevent the possible extinction. These acts include protection of breeding areas, different kinds of fishing restrictions in breeding and distribution areas, new practice in water level control of Lake Saimaa (I, II, III, VI). All possible protection methods should be used simultaneously, because in practice the negative affects of different threats would only be partly diminished by present protection methods.

Being optimistic, I suggest that we have already seen the first reliable signs of recovery of the Lake Saimaa ringed seal population. Protection actions to reduce lair and fishing mortality have served up real “first aid” (VI). An encouraging case is the history of the northern elephant seal (*M. angustirostris*) population, which was very small (approx. 100 seals) at the end of the 19<sup>th</sup> century. Currently, due to conservation management, the extant population size is well over 100 000 seals (McGinnis and Schusterman 1981, Reeves *et al.* 1992, Reijnders *et al.* 1993).

In Lake Saimaa the conflict between fishing and protection is a grave problem and in Finland greater compliance with the Habitats Directive Article 12(4) concerning fishing by-catch is needed (VII). The National Fishing Act, not the Nature Conservation Act, gives the main background to seal protection in water areas. Practically, the central line of the Fishing administration in Finland is to develop and promote fishing including Lake Saimaa, and even inside national as well as so in Natura 2000 areas. To guarantee the best possible future management of Saimaa ringed seal sanctuaries as a minimum state owned water areas inside the Natura 2000 program should be combined with land areas as a single protection unit under the control of a nature protection administration, which would govern national parks and other protected areas.

In Lake Saimaa, communication and education have probably also reduced disturbance of lairing occurrences or sites and reduced the mortality rate due to drowning in fishing tackle, but the influence of this protection method has not been evaluated. At the national level, Finns

are willing to accept the suggested cost of the conservation. Exceptionally, the local people around Lake Saimaa are not (Moisseinen 1997). The success of protection requires communication and education that is interactive, reciprocal and continuous (Meffe *et al.* 1999).

Spatially based protection with special protection areas is basically a suitable method for Saimaa ringed seal protection, due to the site fidelity of the seal. Scattered distribution with several breeding occurrences is a problem, but through the Natura 2000 program all the remaining lairing areas will be protected. There were some suggestions that in an earlier period herds of ringed seals occurred in Lake Saimaa as currently found in Lake Ladoga and in some places in the Baltic Sea (Seppovaara 1958, Anonymous 1966, Sipilä 1993, Sipilä and Medvedev 1993, Sipilä *et al.* 1993, 1996, Kunnasranta *et al.* 1996, Härkönen *et al.* 1998). The density of the ringed seal population may also affect social behaviour. One “idea” in the Natura 2000 program is that population density should increase in the present breeding occurrences, which will be protected by law, as happened in Lake Kolovesi.

The nearly unpolluted freshwater environment of Lake Saimaa provides an opportunity for ringed seals to survive, there is enough stable annual ice cover and snowdrifts for breeding. Present legislation, also gives support to the protection of the Saimaa ringed seal. The Natura 2000 network is the prime element in the protection of the Saimaa stock. In Lake Saimaa the key issue is: How effectively will the state national and regional authorities put the demands of the Habitat Directive and Natura 2000 program in to practice?

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